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<td><strong>Author(s)</strong></td>
<td>隈元，芳一；加藤，義雄；丸山，隆司；白貝，彰宏；吉田，吉一；橋詰，雅</td>
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The absorbed dose in a whole body from 44keV, 105keV X-rays and ⁶⁰Co γ-rays

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(Director: Dr. Tadashi Hashizume)

Abstract

The absorbed dose in the parts of head, arms, abdomen, legs and whole body has been obtained for a homogeneous phantom from the radiations, 44 keV, 105 keV X-rays and ⁶⁰Co γ-rays by measuring the exposure distributions in water phantoms with an ionization chamber. The direction of a phantom was in front, side and at an angle of 45 degrees to the beam. The amount of absorbed dose in the whole body obtained was 0.4 to 1.0 rad for 1R of free air exposure.

Introduction

In the measurement of personal monitoring, the assessment of absorbed dose in terms of personal monitor reading is most important, but the rule of it is not fully established yet. As the monitor is usually loaded on the chest or abdomen of a human body, the measured value of a monitor indicates only the accumulated dose at the location of the monitor.

The ICRP has recommended that the absorbed dose which should be assessed is that in the gonads or
in the bone marrow in case of a whole body exposure. J.R. Jones has determined the relations between
the monitor reading or the exposure to the monitor site and the absorbed dose in the critical organs such
as brain, eyes, skin, gut mucosa, ovaries, testis and average bone marrow. He has measured the
absorbed dose in the Alderson phantom with a LiF thermoluminescent dosimeter in the energy range of 27
keV to 1.25 MeV. The results have been used by E. Pisch in the interpretation of absorbed dose in the
critical organs by the radiophotoluminescent dosimeter encapsulated in the holed cadmium case. H. J.
Delafield has measured the exposure distribution in water phantoms, and determined the method of cal-
culation of absorbed dose by the film badge readily.

The absorbed dose in critical organs, of course, is to be known in radiation hazard, but that in the
whole body is also important in case of a whole body exposure. The ICRP stated about this in the item
25 in ref. (1). Further, the knowledge of the amount of the absorbed dose in the whole body is essential
in radiation accident. W.A. Langmead and S.M.B. Hill have determined the dose of person who experi-
enced an accident in the handling of nuclear power fuels.

In the present work, to determine the dependence of the absorbed dose in the whole body on the direc-
tion of man to the radiations and on the energy, the exposure distributions in water phantoms were mea-
sured with an ionization chamber for three kinds of energies and three kinds of directions. The comparison
of the data with those obtained by other author will be made.

Experiments

(1) Radiation source

Radiation sources used in the experiments were 44 keV, 105 keV X-rays and 60Co γ-rays. The
X-rays were generated at the potential of 95 kV and 230 kV; added filters were 5 mm Al and 1.5 mm
Cu + 0.5 mm Al, respectively. The effective energies were determined by measuring a half value layer
thickness with aluminum and copper wedges. All the following experiments were made at a distance of
3.4 m from the sources. The dose rate was about 0.3, 1.0 and 0.03 R/min for 44 keV, 105 keV X-rays
and 60Co γ-rays, respectively.

(2) Exposure distributions in water phantoms.

![Fig. 1. Experimental arrangement of the measurement of exposure distributions in water phantoms.](image)

Experimental arrangement to measure the exposure distributions in phantoms is shown in Fig. 1.
The phantoms were made of 5 mm thick polyethylene sheet, filled with water. The cross-sections are shown
in Fig. 2, and the height was 60 cm. The center of the chamber was placed at a depth of 15 cm from the
water surface. The field size was 30 × 30 cm. Phantom directions were in front, side and at an angle
of 45 degrees to the incident beams. A Farmer-Baldwin ionization chamber for sub-standard use was
Fig. 2. Exposure distributions for man phantom normalized to the free air exposure 1R and applied the inverse square law correction. Arrow shows the direction of radiation incidence.

used. The energy dependence of it has been measured at the National Physical Laboratory in England. The correction factors are 1.10, 0.99, 1.015 and 1.05 for photon energies of 25, 80, 120 keV and 1.25 MeV
relatively. The measured points in the phantoms were of 2 or 3 cm apart mesh, and to a distance of 1.5 cm from the surface of the phantom. Distributions in Fig. 2 were obtained by normalizing the exposure in the phantom to the free air exposure at the point of the phantom surface and applying the inverse square law corrections.

**Absorbed dose calculation**

The cross-sections of a man phantom used in the calculation of absorbed dose were essentially the same as those used in the measurements of exposure distributions. The sizes are shown in Table 1, in which those of legs, thighs and arms were slightly different. The distributions for these parts were obtained from the data of the similar size phantom by the method in which a sheet of transparent paper was laid over the measured distributions and the line of periphery of the arms, etc. and the combined lines were traced.

**Table 1. Dimensions of Parts of Man Phantom**

<table>
<thead>
<tr>
<th>Part of Phantom</th>
<th>Shape</th>
<th>Major (cm)</th>
<th>Minor (cm)</th>
<th>Length (cm)</th>
<th>Area (cm²)</th>
<th>Volume (cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>elliptical</td>
<td>13</td>
<td>13</td>
<td>20</td>
<td>199</td>
<td>3980</td>
</tr>
<tr>
<td>Chest &amp; Abdomen</td>
<td>&quot;</td>
<td>31</td>
<td>21</td>
<td>60</td>
<td>563</td>
<td>33700</td>
</tr>
<tr>
<td>Thighs</td>
<td>circular</td>
<td>14</td>
<td>30</td>
<td>154</td>
<td>2 × 4620</td>
<td></td>
</tr>
<tr>
<td>Legs</td>
<td>&quot;</td>
<td>11</td>
<td>40</td>
<td>95</td>
<td>2 × 3800</td>
<td></td>
</tr>
<tr>
<td>Arms</td>
<td>&quot;</td>
<td>9</td>
<td>30</td>
<td>64</td>
<td>2 × 1920</td>
<td></td>
</tr>
<tr>
<td>Under arms</td>
<td>&quot;</td>
<td>7</td>
<td>30</td>
<td>39</td>
<td>2 × 1170</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60750</td>
</tr>
</tbody>
</table>

**Table 2. Average absorbed dose of man-phantom exposed to radiation of 1R. (rad)**

<table>
<thead>
<tr>
<th>Part of Phantom</th>
<th>⁶⁰Co 105keV</th>
<th>⁶⁰Co 44keV</th>
<th>⁶⁰Co 45 degree 105keV</th>
<th>⁶⁰Co 44keV</th>
<th>Side 105keV</th>
<th>⁴⁰K 44keV</th>
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</thead>
<tbody>
<tr>
<td>Head</td>
<td>.80</td>
<td>.78</td>
<td>.65</td>
<td>.81</td>
<td>.73</td>
<td>.90</td>
</tr>
<tr>
<td>Chest &amp; Abdomen</td>
<td>.77</td>
<td>.99</td>
<td>.71</td>
<td>.68</td>
<td>.64</td>
<td>.55</td>
</tr>
<tr>
<td>Arms</td>
<td>.89</td>
<td>.97</td>
<td>.87</td>
<td>.89</td>
<td>.97</td>
<td>.87</td>
</tr>
<tr>
<td>Under arms</td>
<td>.91</td>
<td>1.04</td>
<td>1.00</td>
<td>.91</td>
<td>1.04</td>
<td>1.00</td>
</tr>
<tr>
<td>Thighs</td>
<td>.86</td>
<td>.91</td>
<td>.78</td>
<td>.86</td>
<td>.91</td>
<td>.76</td>
</tr>
<tr>
<td>Legs</td>
<td>.86</td>
<td>.95</td>
<td>.79</td>
<td>.86</td>
<td>.95</td>
<td>.79</td>
</tr>
<tr>
<td>Whole body</td>
<td>.62</td>
<td>.97</td>
<td>.76</td>
<td>.77</td>
<td>.78</td>
<td>.70</td>
</tr>
</tbody>
</table>

The areas between the equi-exposure lines were measured with a planimeter. The product of the area, the mid-point value of two lines and the roentgen-rad conversion factors divided by the total area gave the absorbed dose in that part. Values for whole body were obtained by weighing by the weight of each part. About the largest exposure regions, as the representative exposure, 0.3 was added to the smaller value of that region. The R-rad conversion factors used were 0.95, 0.95 and 0.95 for 44 keV, 105 keV X-rays and ⁶⁰Co γ-rays, respectively. Results are shown in Table 2.

**Discussion**

Present results did not include the consideration of the changes of radiation quality in the phantom.
This gave some errors in the calculation of the absorbed dose through the energy dependence of the chamber and of the R-rad conversion factor. Error of exposure reading in the phantom has been discussed in detail by H.J. Delafiied. He estimated that the results were about 5% high at 2 MeV irrespective of depth and that at 1 keV the chamber over-read by about 10% near to the surface and under-read by a few % at 20 cm depth. The R-rad conversion factor changes from 0.92 to 0.96 in the energy range of 30 keV to 1.25 MeV. Moreover, the inhomogeneity of the human body was neglected in the calculation. So, no corrections due to the changes of photon quality have been applied.

Figure 3 shows the comparison of the absorbed dose in the whole body with that in the gut mucosa and bone marrow obtained by A.R. Jones. The results of bone marrow have not differed so much for the frontal, back and rotational irradiation. The points show the present data. Because they were obtained by averaging over the whole body, changes of values with the energy and the direction of beam are rather small. It is possible to say that the absorbed dose in the whole body is close to that in bone marrow.

![Graph showing the comparison of absorbed dose](image)

○ in front; × 45 degrees; ● side

Fig. 3. Comparison of absorbed dose for 1R of free air exposure in whole body and that in critical organs obtained by A.R. Jones (Ref. 3). Points are present data.

The integral dose is affected by the scatter factor and the attenuation of radiation in the human body. The scatter factor is largest around 70 keV and decreases with decreasing field size. If the scatter is neglected, the absorbed dose would be larger when the radiation energy is larger and the path length of radiation is longer (i.e., in case of side incidence). Shielding effects of arms are clearly indicated in Fig. 2 and the absorbed dose in the whole body is smallest in the side irradiation. This shows the importance of the field size or the scatter factor.

References